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Chemical Characterization of Wine Grapes Grown in Japan

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Abstract

Juices of nine grapes, Riesling, Chardonnay, Semillon, Koshu, Cabernet Sauvignon, Cabernet franc, Pinot noir and Muscat Bailey A grown in Kofu, and Concord grown in Shiojiri, both in Japan were analyzed for the compositions of sugars, organic acids, phenolic compounds, nitrogen compounds, and metals. Comparisons were made mainly with the reported compositions of juices of the same varieties of grapes grown in three areas of the U.S.A. with different air temperatures-Prosser, Washington; Davis, California; and Geneva, New York. The air temperatures of the growing areas decrease in the order Davis/Kofu, Shiojiri, Prosser, Geneva. In general, the grapes grown in Kofu and Shiojiri, which are the major part of grape-growing areas in Japan, had less acidity, organic acids, sugars, phenols including pigments, amino acids, metals, etc. than those in the three areas in the U.S.A. in the same varieties. There was some correlation between the air temperature of the growing area, and the total acidity, malic acid content, the ratio of coutaric acid (p-coumaroyl-tartaric acid) to caftaric acid (caffeoyl tartrate) of grape juices, or red skin color. The effect of air temperature on other grape components is also discussed.

Introduction

It is well known that climatic factors, such as temperature, rainfall, fog, humidity, and duration of sunshine, as well as soil, are very important in the successful production of grapes. It has been proven that temperature is usually the most important climatic factor affecting the composition of grapes (1), although composition is also influenced considerably by other seasonal and regional conditions and varies with variety. There have been a number of reports on the relationship between temperature and the composition of grapes, including sugars (3–5), organic acids (6–14), amino acids (6, 14, 15), and phenols including anthocyanins (14, 16–18). Accordingly, Amerine and Winkler (2) segregated the grape-producing areas in California into five climatic regions (I to V) based on heat summation above 50°F (10°C), and discussed the correlation between temperature and grape quality. Under cool climatic conditions, grapes at maturity generally have a high degree of acidity, a low pH, and good color, while under warm or hot conditions they have a high ratio of sugar to acid, and are less delicate, less aromatic, sometimes harsh and coarse, and poorly balanced (2).

In this study, grapes harvested in September and October, 1989 in the central part of Japan-eight varieties in Kofu and Concord in Shiojiri -were used for physical and chemical analy-

ses, and the data obtained were compared with the published data on the composition of grapes grown in Prosser, Washington (Region I; 2,424 degree-days, 1924–1970 (10)); Davis, California (Region IV; 3,780 degree-days (19)); and Geneva, New York (Region I; 2,261 degree-days (20)). The heat summation for the growing season in Kofu is in the range of that of region IV (moderately hot region, 3,501 to 4,000 degree-days), which includes Davis, while that in Shiojiri is in the region II range (moderately cool region; 2,501 to 3,000 degree-days). The mean temperature during the dormant period from November to March between 1983 and 1989 was 5.6°C (42.0°F) for Kofu and 3.5°C (38.3°F) for Shiojiri (21,22).

The growth cycle of grapevines in Japan is the same as in major grape-growing regions in the temperate climate zone of the world. Most vineyards in Japan suffer frequently from heavy rain or high humidity, and sometimes from wind damage caused by typhoons between late August and early October, which is the harvesting time for wine and table grapes.

Thus, the weather conditions for growing grapes in Kofu and Shiojiri (in a moderately cool to warm, wet region) are different from those in the major good quality wine grape-growing areas (cool to moderately cool and dry) of the world. It is generally suggested that in Japan the quality of wines is rather poor compared to that in the major wine grape-growing areas because the grapes are lower in flavoring substances (low levels of acidity, sugar, color and aroma compounds). In order to make wines from such grapes, special practices are required. However, there have been few reports on the flavoring substances of wine grapes grown in Japan.

The aims of this paper are to characterize the chemical compositions of grapes grown in Japan, to compare these with the compositions of wine grapes grown in Prosser, Davis, and Geneva, and to elucidate the relationship between temperature and chemical composition.

Materials Methods

Grapes and juices: Four white grapes: Koshu (2,294 kg), Riesling (417 kg), Chardonnay (284 kg), and Semillon (536 kg), and five red grapes: Cabernet Sauvignon (648 kg), Cabernet franc (764 kg), Pinot noir (220 kg), Merlot (395 kg), and Muscat Bailey A (970 kg, Muscat Hamburg X Bailey) were harvested at commercial maturity in September and October, 1989 from the experimental vineyard of the Institute of Enology and Viticulture, Yamanashi University, Kofu (Table 1). Mature Concord grapes (250 kg) were obtained from a vineyard of Alps Co. Ltd. in the Shiojiri district in Nagano Prefecture. Concord is used as a table grape as well as wine grape in the Shiojiri district. Koshu is the most popular Japanese white wine and table grape variety with pink skin. It has little distinctive varietal flavor characteristics, and is generally believed to be an Oriental-European variety. Muscat Bailey A is the leading Japanese red variety; it is used for red wine production and as a table grape. These berries are large and juicy with a "foxy" flavor. The two Japanese varieties grow easily under Japan's climatic conditions. The nine above-mentioned grapes are referred to the 'Japanese grapes' hereafter.

The most commonly used criteria for wine production are sugar content, acidity, and pH. However, since any grapes harvested in Yamanashi University vineyard seldom have a sugar content over 20° Brix or a ° Brix/acid ratio over 30 before the over-ripe stage, they were harvested on the dates shown in Table 1, after considering the contents of sugars and total acids of grapes, their Brix/acid ratios, and sensory evaluation of wines made from the respective grape varieties over the past several years.

In order to prepare juices for the analysis of hydroxycinnamates such as caftaric and coutaric acids, two samples of 1.5 kg each of destemmed and crushed grapes of each variety were taken at random from the grapes harvested, and independently pressed in two layers of gauze with a hand-operated press

under an atmosphere of CO_2 in a glove box according to the method of Singleton and Trousdale (23). Immediately after pressing, potassium metabisulfite was added to the juices in vinyl bags at a concentration of 1,000 mg (as SO_2)/L. The bags were frozen with dry ice and stored at −20° C until just before use.

For the analysis of juice components other than hydroxycinnamates, juices were prepared as follows. Four white and 6 red grapes (75−300 kg for whites and 100−300 kg for reds) were destemmed and crushed with a horizontal-type destemmer-crusher. The crushed grapes were put in the cage of a Vaslin-type press and pressed very lightly by moving a mobile plate. Free-run juices were collected and their yields were 45−55% [volume of juice collected/weight of grapes used) x 100%]. After pressing the remaining pomace of white grapes in the cage of the press at the maximum pressure of 2.0 kg/cm^2, the press juice was obtained. The free-run juice and press juice portions from the white grapes were combined and used for white wine production. In the case of red grapes, the free-run juice and the remaining pomace in the cage were combined again immediately after draining the free-run juice and used as must for red wine production. Potassium metabisulfite was added to the white or red must to give a concentration of 50 mg/L as SO_2. Two samples (2L each) of the juice of each variety were taken and put in vinyl bags, frozen with dry ice and stored at −20° C until just before use. Samples of the unfrozen juices were used to determine the acidity, pH, individual organic acids, and percentage of sugar. The percentage of sugar was determined with a hand refractometer, type N 20 (Atago Co., Ltd., Tokyo) and expressed as degree Brix. The frozen juice was thawed for use by immersing the container in running water.

Wines: Sugar was added to the must from the white or red grapes in order to give a concentration of about 23° Brix. The musts were inoculated with *Saccharomyces cerevisiae* W3 (24) and fermentation started between 20° C and 22° C.

In making red wines, when the Brix dropped to about two-thirds of the original Brix, the fermenting must was pressed by a Vaslin-type press. The fermentation was then allowed to proceed to completion. After fermentation, the wines were settled for about 4 weeks at 4° C−6° C, and then racked, filtered through membrane filters (0.45 μm), and subjected to spectrophotometric analysis. All fermentations were conducted in duplicate.

Analyses: Duplicate analyses of juice and wine components were carried out and the analytical values given are the averages of the two samples.

The total phenol content was determined according to the method of Slinkard and Singleton (25). The flavonoid and nonflavonoid phenols were determined by the method of Kramling and Singleton (26).

Compositions of sugars (27), organic acids (28), hydroxy cinnamates such as caftaric acid and coutaric acid (23,29), and amino acids (30) were analyzed by high performance liquid chromatography.

The protein content was analyzed by the micro-Kjeldahl method (31)(Kjeldahl nitrogen X 6.25).

The ash was determined by the method of Amerine and Ough (32). Individual cations in the ash were determined by atomic absorption spectrometry with a Hitachi, type 170−30, atomic absorption spectrophotometer.

Spectral analysis of red wines was carried out according to the methods of Somers and Evans (33,34).

Results and Discussion

Sugars and glucose/fructose ratio: During the ripening of grapes, sugars increase rapidly. The ° Brix of wine grapes usually reaches above 20 at full maturity in most of the premium wine-producing regions of the world. Amerine (35) found that in warm regions grapes attained a higher sugar content, and in warm seasons in the same region they ripened earlier and attained a higher sugar content than in cool seasons.

The mean heat summations in Kofu and

Shiojiri during the period from 1 April to 30 October (the growing season) in 1989 were 3,788 (21) and 2,947 (22) degree-days, respectively. The annual rainfall in 1989 was 1,067 mm in Kofu and 1,093 mm in Shiojiri. The total rainfall during the 1989 growing season was 804 mm in Kofu and 852 mm in Shiojiri, while during the dormant period from 1988 to 1989 it was 252 mm in Kofu and 301 mm in Shiojiri. The 1989 growing season was, generally, a nearly average year in terms of heat summation, rainfall, crop yield, and grape and wine quality.

Although the heat summation for Kofu is higher than that for Prosser, the °Brix of all the grapes in Table 1 was lower than 20, whereas that of Prosser for the same varieties was more than 20 (8,10). The °Brix of Concord juices varied from 15.4 to 17.8 for grapes in Geneva (heat summation: 2,261 degree-days) in 1966–1969 and from 11.50 to 20.7 in New York State in 1967–1972 (36). The values in Geneva were higher than the °Brix for Concord in Shiojiri (heat summation: 2,947 degree-days). These findings differ from Amerine's conclusion (35) that the higher the heat summation, the higher the sugar content in the same variety.

Kliewer (4) reported that in Davis the glucose/fructose ratio tended to be lower in warm seasons than in cool ones. The glucose/fructose ratios for Riesling, Semillon, Chardonnay, Cabernet Sauvignon, and Pinot noir varieties in Davis were less than 1.0 (0.78 to 0.96) at an early and late stage of maturity. The glucose/fructose ratios in Table 1 for the same varieties as above were more than 1.0 (1.10 to 1.24), except that the ratios for the Chardonnay and Semillon varieties were 0.87 and 0.82, respectively. The ratio for Concord in Shiojiri (1.00) was similar or slightly higher than the ratios (0.93 (36), 1.02 (37), and 0.74 (38)) for Concord in the eastern United States. These findings suggest that air temperature is not the only major factor affecting the glucose/fructose ratio.

Acidity, °Brix/acid ratio and tartrate/malate ratio : A comparison of the total acidity of grapes of five varieties in Davis (39–42) and Prosser (8, 10, 43) showed that high temperature was associated with low acidity in the grape juices. The total acidity of grapes in cool Prosser was always higher than that of grapes of the same variety in warm Kofu or Davis, although the actual values varied with variety. The average total acidity of each grape variety at maturity was 0.91 g/L for 16 samples of the juices of Riesling grapes in Prosser (7, 8, 43) and 0.62 g/L for 5 samples in Davis (38–40, 42); 0.79 g/L for 16 samples of Semillon in Prosser (7, 8, 43) and 0.60 g/L in Davis (42); 0.99 g/L for 19 samples of Chardonnay in Prosser (7, 8, 43, 44) and 0.60 g/L in Davis (42); 0.74 g/L for 11 samples of Cabernet Sauvignon in Prosser (7, 8, 44) and 0.69 g/L for 4 samples in Davis (42, 45); and 0.84 g/L for 26 samples of Pinot noir in Prosser (7, 8, 10, 43, 44) and 0.77 g/L in Davis (42). On the other hand, the total acidity for 9 varieties in Kofu and Shiojiri was between 0.55 and 0.79 g/L with an average of 0.71 g/L, and the individual values for each of Riesling, Semillon, Chardonnay, Cabernet Sauvignon, and Pinot noir in Kofu were not consistent with those for the same varieties in Davis although the heat summations of Davis and Kofu are similar to each other. The total acidity (0.55 g/L) for Concord in Shiojiri was much lower than that (1.15–1.64 g/L) for a six-year period in the eastern United States (46).

The sugar/acid ratio has been suggested to be one of the best criteria for prediction of proper maturity (47). The average ratio for 5 varieties in Prosser was 23.8 for 9 samples of Riesling (7, 8, 10), 27.2 for 9 samples of Semillon (7, 8, 10), 23.8 for 10 samples of Chardonnay (7, 8, 10, 44), 29.6 for 11 samples of Cabernet Sauvignon (7, 8, 10, 44), and 27.2 for 10 samples of Pinot noir (7, 8, 10, 44). The average ratio for grapes in Davis was 30.7 for 4 samples of Riesling (38–40), and 35.3 for 2 samples of Cabernet Sauvignon (40). The ratio for Riesling and Cabernet Sauvignon in Davis was higher than that for the same two varieties in Prosser. On the other hand, the ratios in Kofu was 26.2 for Riesling, 24.1 for Chardon-

Sauvignon, and 24.5 for Pinot noir, 20.3 for Koshu, 22.4 for Cabernet franc, and 22.2 for Muscat Bailey A. Thus, the values in Kofu were between 20.3 and 24.1 with an average of 22.9, and were smaller than the values for Riesling, Semillon, Chardonnay, Cabernet Sauvignon, and Pinot noir in Prosser and much lower than the values for Riesling and Cabernet Sauvignon in Davis because the °Brix of the Japanese grapes was lower. The ratio for Riesling, Chardonnay, Muscat Bailey A, and Koshu in Kofu increased gradually with ripening because of a large decrease in acidity and a small increase in sugar, but the changes in °Brix, acidity, and the °Brix/acid ratio of Semillon, Cabernet franc, and Cabernet Sauvignon were small until a few weeks after their harvesting dates (optimum maturity) (Table 1).

Table 1. Harvesting dates of grapes, and sugar content and composition of organic acids in the juices.

Variety	Harvesting date (1989)	°Brix	Fructose (F) (g/100ml)	Glucose (G) (g/100ml)	G/F	pH	Total acidity (g/100ml)
White grapes							
Koshu	Oct. 10	15.6	7.02	7.72	1.10	3.30	0.77
Riesling	Sep. 25	16.0	5.79	6.79	1.17	3.40	0.61
Chardonnay	Sep. 12	16.9	7.51	6.52	0.87	3.61	0.70
Semillon	Sep. 13	17.2	8.55	7.01	0.82	3.11	0.78
Red grapes							
Cabernet Sauvignon	Oct. 16	15.8	7.38	8.04	1.10	3.48	0.74
Cabernet franc	Oct. 2	17.5	7.14	7.58	1.06	3.29	0.78
Pinot noir	Aug. 30	16.4	6.46	8.04	1.24	3.58	0.67
Muscat Bailey A	Oct. 16	17.5	9.23	8.18	0.89	3.42	0.79
Concord	Sep. 29	14.2	6.10	6.07	1.00	3.33	0.55
		16.3	7.23	7.33	1.01	3.39	0.71

Variety	Citric acid	Tartaric acid (T)	Malic acid (M) (g/100ml)	Lactic acid	Acetic acid	Total	T/M
White grapes							
Koshu	0.04	0.60	0.42	trace	0	1.06	1.43
Riesling	0.04	0.45	0.21	trace	0	0.70	2.14
Chardonnay	0.06	0.42	0.41	trace	trace	0.89	1.02
Semillon	0.04	0.62	0.37	0	0	1.03	1.68
Red grapes							
Cabernet Sauvignon	0.08	0.47	0.45	0	0	1.00	1.04
Cabernet franc	0.04	0.57	0.37	0	0	0.98	1.54
Pinot noir	0.05	0.51	0.32	trace	0	0.88	1.59
Muscat Bailey A	0.05	0.52	0.59	0	0	1.16	0.88
Concord	0.05	0.44	0.22	trace	trace	0.71	2.00
Average	0.05	0.51	0.37	trace	trace	0.93	1.48

Nagel et al. (10) showed that malate in grapes in Prosser was higher than in the same variety in Davis (42), whereas tartrate was very similar in amount. Both tartrate and malate were higher in Riesling, Chardonnay, Semillon, Cabernet Sauvignon, and Pinot noir in Prosser (10) than in the same varieties in Kofu (Table 1). Malate in three white grapes (Riesling, Chardonnay, and Semillon) in Kofu was similar to that in Davis, but smaller in two red grapes (Cabernet Sauvignon and Pinot noir), whereas tartrate in Davis was higher than that in Kofu in the whites as well as in the reds. Both tartrate and malate in Concord from Shiojiri were lower than in the eastern United States (48). The tartrate/malate ratio in the three whites and Cabernet Sauvignon in Kofu was smaller than that in Davis. The ratio (2.00) for Concord in Shiojiri was higher than that (1.40) for a four-year period in the eastern United States (48). These results were consistent with those reported by several researchers (6, 11–14), showing that grapes ripened at cool temperatures were considerably higher in total acidity, particularly in malic acid, than fruit ripened at high temperatures, and that the percent malate and the percentage of total acidity due to malate was greater under cool temperatures than under warm ones.

Phenolic compounds: Table 2 shows the contents of total phenol, flavonoid and non-flavonoid phenols, and hydroxycinnamates, and the spectral evaluation of the red wines made from the 5 red grapes. The content of total phenol ranged from 185 to 881 mg/L with an average of 395 mg/L in the juices. The high total phenol content in the juices from Koshu, Semillon, Cabernet franc, and Muscat Bailey A was due to a high content of flavonoid phenol originating from skins since flavonoid phenol is present chiefly in skins, stems, and seeds, but very little is found in the readily expressed juice.

Table 2. Composition of phenolic compounds in the juices from the Japanease grapes and spectral evaluation of red wines made from the grapaes.

Variety	Total phenol (mg/L, as gallic acid)	Flavonoid	Nonflavonoid	Caftaric acid (Ca)	Coutaric acid (Cu)	Cu/Ca
White grapes						
Koshu	420	184	236	203	2	0.010
Riesling	185	45	140	60	2	0.033
Chardonnay	272	109	163	79	2	0.025
Semillon	405	197	208	111	1	0.009
Red grapes						
Cabernet Sauvignon	265	11	254	107	3	0.028
Cabernet franc	505	264	241	176	6	0.035
Pinot noir	254	58	201	100	3	0.030
Muscat Bailey A	881	383	498	261	12	0.046
Concord	368	20	348	207	32	0.155
Average	395	141	254	145	7	0.048

Variety	pH	Total SO_2 (mg/L)	Total phenol (mg/L)	Color density ($A_{520}+A_{420}$)	Color hue (A_{420}/A_{520})	Wine color (A_{520})	Wine color in acid (A_{520} at<pH 1)
Red grapes							
Cabernet Sauvignon	3.70	7	855	3.68	0.85	1.99	2.50
Cabernet franc	3.36	4	450	1.97	0.85	1.06	1.41
Pinot noir	3.68	42	1540	3.90	0.93	2.02	3.33
Muscat Bailey A	3.58	7	1513	6.53	0.76	3.70	8.10
Average	3.58	15	1090	4.02	0.85	2.19	3.84

Hydroxycinnamates such as caftaric acid and coutaric acid comprised 43 to 87% of non-flavonoid phenol with an average of 60% in the juices (Table 2). Difficult-to-press varieties such kas Koshu, Muscat Bailey A and Concord had greater amounts of caftaric acid, while Riesling and Chardonnay had lower amounts. All the varieties had very low amounts of coutaric acid except for Concord. A comparison was made of the contents of caftaric acid and coutaric acid in juices from the grapes of selected varieties in Prosser, Shiojiri, Kofu, and Davis because data are available to compare hydroxycinnamates in the juices of the selected varieties.

The content of caftaric acid was not correlated with the air temperatures of the growing sites. However, the ratio of coutaric acid to caftaric acid in the juices of Prosser, Shiojiri, Davis, and Kofu tended to increase in that order (the order is essentially that of air temperature). The ratios were 0.11 in Prosser (49), 0.08 in Davis (50), and 0.03 in Kofu for Riesling; 0.20 in Prosser (44, 49) 0.11 in Davis (50, 51), and 0.03 in Kofu for Chardonnay; 0.11 in Prosser (49), 0.06 (50) and 0.03 (51) in Davis, and 0.01 in Kofu for Semillon; 0.21 (44) and 0.24 (49) in Prosser, 0.08 in Davis (50), and 0.03 in Kofu for Cabernet Sauvignon; 0.22 (44), 0.26 (44), and 0.13 (49) in Prosser, 0.06 in Davis (50), and 0.03 in Kofu for Pinot noir; and 0.20 in Shiojiri and 0.05 in Davis (50) for Concord.

One of the most clearly demonstrated effects of climate on the composition of grapes is that of temperature on berry color, as described by Singleton and Esau (16). They also showed that under a climate warm enough to mature grapes satisfactorily, the cooler the region or season the more anthocyanin pigment is produced in the grape skin. Singleton found that the tannin content of skins increases during ripening at about the same rate as the color (52). Generally, the Japanese red wines were poorer in red pigments (Table 2) than Australian and French wines made in cooler regions (53–55) although the comparison could not be made between the same varieties. The average color density, wine color at wine pH, and wine color at pH <1 were 4.30 (3.53), 2.39 (1.99), and 6.63 (6.39), respectively, for samples of young Gamay wines in Beaujolais in 1974 (for 15 samples in young Gamay wines in 1975) (53). In South Australia, the average color density, wine color at wine pH and wine color at pH<1 were 7.31 (7.28), 4.32 (4.36), and 21.5 (21.4), respectively, for 14 samples of young Cabernet Sauvignon red wines (for 18 samples of young Schiraz red wines) (49). Also, the average color densities of 6 young red wines in South Australia in 1975 and 6 aged red wines from 1960 to 1973 were 8.5 and 7.24, respectively (56). The average color density, wine color at wine pH and wine color at pH<1 of the 4 Japanese red wines were 4.02, 2.19, and 3.84, respectively (Table 2). Golodria and Suyatinov (17), Kliewer (18), and Buttrose et al. (14) showed that high day and also high night temperatures markedly inhibited pigment formation in many varieties of red and black grapes. The mean August-September temperatures in 1989 in Kofu and Shiojiri were 23.7° C and 21.6° C, respectively, and the mean maximum and minimum temperatures in August-September in 1989 were 29.2° C and 19.9° C in Kofu, and 27.8° C and 17.2° C in Shiojiri. The duration of sunshine in September (161 hours in Shiojiri and 144 hours in Kofu in 1989) is the shortest of the year in Japan. Therefore, the low pigments in the Japanese red wines might be due to the inhibition of the formation of pigments by the high air temperature and low light intensity (6, 18, 57–60) during the maturation period of grapes although there are distinct differences between varieties in their need for light.

Wine color hue is the ratio of absorbance at 420 nm to that at 520 nm at wine pH. The hue was between 0.54 and 0.86 with an average of 0.68 in some young red wines in South Australia and between 0.78 and 1.1 with an average of 1.01 in aged wines (55). Low wine colors at both wine pH and pH<1 may generally be due to the oxidation of the wines. The Japanese wines analyzed here seemed to be slightly oxidized because the values for the hues of the

Table 3. Nitrogen and protein contents of the juices.

Variety	Total nitrogen content in			Soluble protein-nitrogen (SPN)	(SPN X 6.25, soluble protein)
	Total juice	Supernatant	Precipitate (mg/L)		
White grapes					
Koshu	331	206	66	10	63
Riesling	181	129	45	14	88
Chardonnay	333	269	88	13	81
Semillon	448	355	119	26	163
Red grapes					
Cabernet Sauvignon	374	291	71	7	44
Cabernet franc	314	213	77	13	81
Pinot noir	302	243	73	10	63
Muscat Bailey A	460	355	79	13	81
Concord	273	198	61	13	81
Average	335	251	75	13	81

Japanese wines were in the range of the hues of the aged rather than in those of the young Australian red wines.

Nitrogen compounds: Total nitrogen in the Japanese juices ranged from 181 to 460 mg/L with an average of 335 mg/L (Table 3). The average nitrogen content in the supernatants of the juices was 75% of the total nitrogen in the juices. Total nitrogen content was compared among the juices from grapes of the same varieties grown in Davis and Kofu. The juices of Davis (56, 61) always contained larger quantities of total nitrogen than those of Kofu. Soluble protein nitrogen varied over a range of 7 to 26 mg/L with an average of 13 mg/L in the Japanese juices. The average proportion of soluble protein nitrogen of the total nitrogen in the supernatants was 5.6% in the Japanese juices. The content of proteins could not be compared between the Japanese juices and American ones because little information is available on the content of proteins in juices in the U.S.A.

The amino acid nitrogen fraction (calculated from the values in Table 4) on average accounted for about 35% of the total nitrogen (Table 3) in the Japanese juices. This value was much lower than the proportions of the free amino acid nitrogen fraction of total nitrogen in the juices of 26 red-and 23 white-wine varieties (53–76%) (61) and 28 table varieties (60–90%) (56) in Davis. A comparison was made of amino acid composition between the juices from grapes of the same variety, but harvested at different places, i.e. Davis and Kofu (56, 61). Proline and arginine were the predominant amino acids in Riesling, Chardonnay, Semillon, Cabernet Sauvignon, and Pinot noir grapes of both Davis and Kofu, but the content of arginine for Semillon in Kofu was about three times that of proline. Although the proline content varied significantly in the same variety with area (air temperature), the proportion of proline in the total amino acids was not appreciably different in most of the varieties. The proline proportions of the total amino acids in the juices of Davis (61), Oakville (62), and Kofu were 37, 27, and 27% for Riesling, 42, 47, and 43% for Chardonnay, 33, 17, and 27% for Semillon, 36, 57, and 52 % for Cabernet Sauvignon, and 20, 20, and 19% for Pinot noir, respectively. Proline content was always much larger in the Davis juices than in those of Kofu and Oakville. Franzy and

Poux (15), Kliewer and Lider (6), and Buttrose et al. (14) found larger amounts of proline in grapes grown under warm cultural conditions than in those grown under cool conditions. However, the findings obtained here indicate that proline content is not influenced only by air temperature (heat summation).

Metal content: The metal contents of the juices and wines from the Japanese grapes are given in Tables 5. In the wines, the major cations, potassium and sodium, were higher in the red wines than in the white wines. The metal content of the Japanese wines is compared with that of California wines (63–65) because little information is available on the metal content of grape juices in the U.S.A. Average potassium and sodium contents of 899 and 50 mg/L (63), 910 and 70mg (64), or 803 and 51 mg/L (65), respectively, have been reported for California white table wines, and 1,260 and 131 mg/L (63), 1,230 and 100 mg/L (64), or 1,102 and 53mg/L (65) for red table wines. The potassium content of the Japanese wines was lower than that of the California wines. The sodium content of the Japanese wines was similar to that of the California wines.

These results show that there were differences in the composition of grapes of the same variety grown in Prosser, Geneva, Shiojiri, Kofu, and Davis. Although the air temperature of the growing site is one of the important factors influencing the composition of grapes,

Table 4. Amino acid composition of the juices.

Amino acid	White grapes				Red grapes				
	Koshu	Riesling	Chardonnay	Semillon	Cabernet Sauvignon	Cabernet franc	Pinot noir	Muscat Bailey A	Concord
					(mg/L)				
Asp	14	13	39	8	27	17	16	27	54
Thr	73	32	125	55	46	34	56	89	130
Ser	35	13	92	34	29	38	20	43	20
Glu	60	29	148	33	94	63	55	153	46
Pro	598	79	777	112	621	321	113	153	28
Gly	3	1	7	3	3	1	2	8	5
Ala	115	35	180	50	92	98	68	269	315
Val	6	5	30	12	19	19	14	13	7
Met	trace	3	trace	2	trace	2	trace	4	trace
Ile	trace	2	11	8	7	7	4	5	trace
Leu	5	4	14	13	11	13	11	12	4
Tyr	trace	trace	10	5	trace	6	trace	11	trace
Phe	5	3	22	9	17	27	trace	19	8
Lys	trace	trace	2	3	1	3	3	3	trace
His	6	3	20	6	9	11	7	7	4
Arg	176	76	174	297	124	176	204	334	56
Total	1,096	295	1,653	650	1,100	836	573	1,150	667

the differences were undoubtedly affected by other variables, including climatic conditions other than temperature, soil type or soil minerals, harvesting practices, grape variety, cultural practices, and processing conditions.

Table 5. Metal content of the juices and wines.

Variety	Cations							K/Na	Ash (g/L)
	K	Ca	Mg (mg/L)	Zn	Na	Fe	Cu		
White grapes									
Koshu	600	14	49	3	41	1	3	14.6	1.62
Riesling	600	16	38	3	39	1	2	15.4	2.10
Chardonnay	710	19	31	3	46	7	2	15.4	2.54
Semillon	980	15	46	3	56	3	2	17.5	2.76
Red grapes									
Cabernet Sauvignon	695	18	34	3	47	1	1	14.8	2.30
Cabernet franc	1015	23	38	2	79	4	1	12.8	3.35
Pinot noir	695	8	37	3	47	trace	8	14.8	2.50
Muscat Bailey A	1210	13	54	2	69	5	1	17.5	4.05
Concord	591	2	20	3	153	4	1	3.9	1.12
Average	788	14	39	3	64	3	2	14.1	2.48
White grapes									
Koshu	366	14	45	3	40	2	2	9.2	1.52
Riesling	460	11	39	3	33	2	1	13.9	2.08
Chardonnay	559	12	34	3	49	1	4	11.4	2.10
Semillon	404	14	32	3	44	1	4	9.2	1.28
Average	447	13	38	3	42	2	3	10.9	1.75
Red grapes									
Cabernet Sauvignon	900	19	39	3	42	3	trace	21.4	4.58
Cabernet franc	775	21	39	3	57	5	2	13.6	2.38
Pinot noir	970	7	39	3	51	5	3	19.0	2.84
Muscat Bailey A	832	16	39	3	50	2	trace	16.6	3.64
Average	869	16	38	3	50	4	1	17.7	2.86

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References

1. Weaver, R.J. Grape Growing. pp43–46. John Wiley & Sons, New York (1976).
2. Amerine, M.A. and A.J. Winkler. Composition and quality of musts and wines of California grapes. Hilgardia 15:493–675 (1944).
3. Kliewer, W.M., L.A. Lider and H.B. Schultz. Influence of artificial shading of vineyards on the concentration of sugar and organic acid in grapes. Am. J. Enol. Vitic. 18: 78–86(1967).
4. Kliewer, W.M. The fructose-glucose ratio of *Vitis vinifera* grapes. Am. J. Enol. Vitic. 18: 33–41 (1967).
5. Sepúlveda, G. and W.M. Kliewer. Effect of high temperature on grape vines (*Vitis vinifera* L.). II. Distribution of soluble sugars. Am. J. Enol. Vitic. 37(1):20–25 (1986).
6. Kliewer, W.M. and A.L. Lider. Effects of day temperature and light intensity on growth and composition of *Vitis vinifera* L. fruits. J. Amer. Soc. Hort. Sci. 95: 766–769 (1970).
7. Clore, W.J., C.W. Nagel, G.H. Carter, V. P. Brummund, and R.D. Fay. Wine-grape production studies in Washington. Am. J. Enol. Vitic. 23: 18–25 (1972).
8. Nagel, C.W., M.T. Atallah, G.H. Carter and W.J. Clore: Evaluation of wine grapes grown in Washington. Am. J. Enol. Vitic. 23(1): 14–17 (1972).
9. Ferré, L. L'analyse des moûts dans l'état actuel de nos connaissances et les renseignements d'ordre pratique qui puevent en découler. Chim. et Ind. Special No. pp582–588 (1925).
10. Nagel, C.W., J.R. Powers, M.T. Atallah, W.N. Sawaya, and G.H. Carter. Malate and tartrate contents of musts and wines from grapes produced in Washington. Am. J. Enol. Vitic. 23(4): 144–151 (1972).
11. Kliewer, W.M. Effect of temperature on the composition of grapes grown under field and controlled conditions. Amer. Soc. Hort. Sci. 93: 797–806 (1968).
12. Kliewer, W.M. Berry composition of *Vitis vinifera* cultivars as influenced by photo-and nycto-temperatures during maturation. J. Amer. Soc. Hort. Sci. 98: 153–159 (1973).
13. Kliewer, W.M. Effect of day temperature and light intensity on concentration of malic and tartaric acids in *Vitis vinifera* L. grapes. J. Amer. Soc. Hort. Sci. 96: 372–377 (1971).
14. Buttrose, M.S., C.R. Hale, and W.M. Kliewer. Effect of temperature on the composition of Cabernet Sauvignon berries. Am. J. Enol. Vitic. 22: 71–75 (1971).
15. Flanzy, C. and C. Poux. Note sur la teneur en acides aminés du moût de raisin et du vin en fonction des conditions de l'lannée (maturation et fermentation). Ann. Technol. Agr. 14: 87–91 (1965).
16. Singleton, V.L. and P. Esau. Phenolic substances in grapes and wine, and their significance. Advan. Food Res., Suppl. 1. pp 122–130 (1969).
17. Golodriga, P. Ya. and A. Suyatinov. Onekotorykh fakyorakh vliyayuschchikh na nakoplenie krasyashchikh veschestv v yagodakh. Vinodelie i Vinogradarstov SSSR. 26 (4): 29–32 (1966).
18. Kliewer, W.M. Effect of day temperature and light intensity of coloration of *Vitis vinifera* L. grapes. J. Amer. Soc. Hort. Sci. 95: 693–697 (1970).
19. Winkler, A.J., J.A. Cook, W.M. Kliewer, and L.A. Lider. General Viticulture pp64–66. University of California Press, Berkeley (1974).
20. Climatography of the United States No.81, National Oceanic and Atmospheric Administration. National Climatic Center, Asheville, N.C. (1982).
21. Climatological data reports, Kofu Local Meteorological Observatory, Japan (1990).
22. Climatological data reports, Matsumoto Local Meteorological Observatory, Japan (1990).

23. Singleton, V.L. and E. Trousdale. White wine phenolics: varietal and processing differences as shown by HPLC. Am. J. Enol. Vitic. 34: 27–34 (1983).
24. Isami Yokotsuka. Studies on Japanese wine, Part 8. Selection of superior wine yeasts. Bulletin of the Research Institute of Fermentation (Journal of the Institute of Enology and Viticulture), Yamanashi University (Japan). 1: 63–69 (1954).
25. Slinkard, K. and V.L. Singleton. Total phenol analysis: automation and comparison with manual methods. Am. J. Enol. Vitic. 28: 49–55 (1977).
26. Kramling, T.E. and V.L. Singleton. An estimate of the nonflavonoid phenols in wines. Am. J. Enol. Vitic. 20: 86–91 (1989).
27. Walborg, E.F. Jr. and L. Christensson. A colorimetric method for the quantitative determination of monosaccharides. Anal. Biochem. 13: 186–193 (1965).
28. Yokotsuka, K., T. Matsudo, and N. Nishino. Analysis of organic acids in wines by high performance liquid chromatography using a continuous-flow, dual spectrophotometric detection system. J. Inst. Enol. Vitic., Yamanashi Univ. 21: 17–25 (1986).
29. Yokotsuka, K. Effect of press design and pressing pressures on grape juice components. J. Ferment. Bioeng. 70(1): 15–21 (1990).
30. Yokotsuka, K., T. Ebihara., and T. Sato. Comparison of soluble proteins in juice and wine from Koshu grapes. J. Ferment. Bioeng. 21(4): 248–253 (1991).
31. Horowitz, W. (ed.): A.O.A.C., 12th ed. pp 927–928. Method 47.021. Association of Official Analytical Chemists, Washington, DC (1975).
32. Amerine, M.A., and C.S. Ough. Methods for Analysis of Musts and Wines. 341 pp. John Wiley and Sons, New York (1980).
33. Somers, T.C. and M.E. Evans. Wine quality: Correlations with colour density and anthocyanin equilibria in a group of young red wines. J. Sci. Fd Agric. 25: 1369–1379 (1974).
34. Somers, T.C. and M.E. Evans. Spectral evaluation of young red wines: Anthocyanin equilibria, total phenolics, free and molecular SO_2, "chemical age". J. Sci. Food Agric. 28: 79–287 (1977).
35. Amerine, M.A: Acids, grapes, wines and people. Am. J. Enol. Vitic. 15(2): 106–115 (1964).
36. Rice, A. C. Chemistry of winemaking from native American grape varieties, Chemistry of Winemaking, Advances in Chemistry Series 137, American Chemical Society, Washington, D. C. pp91–93 (1974).
37. Lott, R.V. Hort. Res. 7:126–134 (1967).
38. Lott, R.V. and H. C. Barrett. The dextrose, levulose, sucrose, and acid content of the juice from 39 grape clones. Vitis. 6:257–268 (1967).
39. Ough, C.S. Substances extracted during skin contact with white musts. I. General wine composition and quality changes with contact time. Am. J. Enol. Vitic. 20:93–100 (1969).
40. Ough, C.S. and V.L. Singleton. Wine quality prediction from juice Brix/acid ratio and associated compositional changes for 'White Riesling' and 'Cabernet Sauvignon'. Am. J. Enol. Vitic. 19:129–138 (1968).
41. Arnold, R.A. and A.C. Noble. Effect of pomace contact on the flavor of Chardonnay wine. Am. J. Enol. Vitic. 30(3): 179–181 (1979).
42. Kliewer, W.M., L. Howarth, and M. Omori. Concentrations of tartaric acid and malic acid and their salts in Vitis vinifera grapes. Am. J. Enol. Vitic. 18:42–54 (1967).
43. Carter, G.H., C.W. Nagel, J. Nelson, M. Atallah, T. Hohnson, R. Early, and J. Clore. A summary of experimental testing of grape varieties for wine in Washington. Am. J. Enol. Vitic. 25(2): 92–98 (1974).
44. Nagel, C.W., J.D. Baranowski, L.W. Wulf, and J.R. Powers. The hydroxycinnamic acid ester content of musts and grape varieties grown in the Pacific Northwest. Am. J. Enol. Vitic. 30(3): 198–201 (1979).
45. Amerine, M.A. and G. Thoukis. The glucose-fructose ratio of California grapes. Vitis. 1: 24–229 (1958).

46. Rice, A. C. Chemistry of winemaking from native American grape varieties, Chemistry of Winemaking, Advances in Chemistry Series 137, American Chemical Society, Washington, D. C. pp95–96 (1974).
47. Amerine, M.A. and A.J. Winkler. California wine grapes: Composition and quality of their musts and wines. Calif. Agr. Expt. Sta. Bull. 794, pp83 (1963).
48. Rice, A. C. Chemistry of winemaking from native American grape varieties, Chemistry of Winemaking, Advances in Chemistry Series 137, American Chemical Society, Washington, D. C. pp95–96 (1974).
49. Ong, B.Y. and C.W. Nagel. Hydroxycinnamic acid-tartaric acid ester content in mature grapes and during the maturation of White Riesling. Am. J. Enol. Vitic. 29(4): 277–281 (1978).
50. Singleton, V.L., J. Zaya, and E.K. Trousdale. Caftaric and coutaric acids in fruit of *Vitis*, Phytochemistry. 25(9): 2127–2133 (1986).
51. Singleton, V.L., J. Zaya, E. Trousdale, and M. Salgues. Caftaric acid in grapes and conversion to a reaction product during pressing. Vitis. 23: 113–120 (1984).
52. Singleton, V.L. The total phenolic content of grape berries during the maturation of several varieties. Am. J. Enol. Vitic. 17: 126–134 (1966).
53. Jackson, M.G., C.F. Timberlake, P. Bridle, and Lioyd. Red wine quality: Correlations between colour, aroma and flavour and pigment and other parameters of young Beaujolais. J. Sci. Food Agric. 29:715–727 (1978).
54. Somers, T.C. and M.E. Evans. Wine quality: Correlations with colour density and anthocyanin equilibria in a group of young red wines. J. Sci. Food Agric. 25: 1369–1379 (1974).
55. Somers, T.C. and M.E. Evans. Spectral evaluation of young red wines: Anthocyanin equilibria, total phenolics, free and molecular SO_2 "chemical age". J. Sci. Food Agric. 28: 279–287 (1977).
56. Kliewer, W.M. Free amino acids and other nitrogenous substances of table grape varieties. J. Food Sci. 34: 274–2278 (1969).
57. Naito, R., S. Kyo, and T. Sumi. Studies on the coloration of grapes. VI. Effects of shading on the color and pigmentation of Muscat Bailey A. J. Japan. Soc. Hort. Sci. 34: 145–151 (1965).
58. Naito, R. Studies on the coloration of grapes. V. Influence of light intensity on the coloration and pigmentation in some black and red grapes. J. Japan. Soc. Hort. Sci. 33: 213–220 (1964).
59. Naito, R. Studies on the coloration of grapes. VII. Behavior of anthocyanins in the skin of some black and red grapes as affected by light intensity. J. Japan. Soc. Hort. Sci. 35: 225–232 (1966).
60. Weaver, R.J. and B.M. Stanley. Influence of light on color development in *Vitis vinifera* grapes. Am. J. Enol. Vitic. 11: 179–184 (1960).
61. Kliewer, W.M. Free amino acids and other nitrogenous fractions in wine grapes. J. Food Sci. 35: 17–21 (1970).
62. Huang, Z. and C.S. Ough. Effect of vineyard locations, varieties, and rootstocks on the juice amino acid composition of several cultivars. Am. J. Enol. Vitic. 40(2): 135–139 (1989).
63. Cox, R.J., R. Eitenmiller, and J.J. Powers. Mineral content of some California wines. J. Food Sci. 42(3): 849–850 (1977).
64. Berg, H.W., Min Akiyoshi, and M.A. Amerine. Potassium and sodium content of California wines. Am. J. Enol. Vitic. 30(1): 55–57 (1979).
65. Ough, C.S., E.A. Crowell, and J. Benz. Metal content of California wines. J. Food Sci. 47: 825–828 (1982).